MEMORANDUM REPORT ARBRL-MR-03157

KINEMATIC INVESTIGATION HUGHES HELICOPTER 7.62MM CHAIN GUN

R. P. Kaste

February 1982

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

Destroy this report when it is no longer needed.
Do not return it to the originator.

Secondary distribution of this report by originating or sponsoring activity is prohibited.

Additional copies of this report may be obtained from the National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161.

The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

The use of trade names or manufacturers' names in this report does not constitute indorsement of any commercial product.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Memorandum Report ARBRL-MR-03157	2. GOVT ACCESSION NO. AD-A113 114	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) KINEMATIC INVESTIGATION HUGHES HELICOPTER 7.62 mm CHAIN GUN		5. TYPE OF REPORT & PERIOD COVERED Memorandum Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) R.P. Kaste		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Ballistic Research Laboratory ATTN: DRDAR-BLI Aberdeen Proving Ground, MD 21005		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 1L162617AH19
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Armament Research & Development Command U.S. Army Ballistic Research Laboratory ATTN: DRDAR-BL Aberdeen Proving Ground, MD 21005		12. REPORT DATE February 1982
		13. NUMBER OF PAGES 58
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release, distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Chain Gun
Power
Stud Roller
Angular Position
Linear Position

20. ABSTRACT (Continue on reverse side if necessary and identify by block number) jmk

A kinematic study of the Hughes Helicopter 7.62mm Chain Gun was performed to determine the power required to operate the weapon and loads on the stud roller due to the various components of the weapon. Using a 24-volt battery system the gun drew up to 60 amperes to start and operated on 22 amperes. The stud roller carries a load up to 497 Newtons.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

I. INTRODUCTION

The Small Caliber Weapons System Laboratory (SCWSL) of the U. S. Army Armament Research and Development Command (ARRADCOM) contacted the Mechanics and Structures Branch (M&SB) of the Interior Ballistics Division (IBD), Ballistic Research Laboratory (BRL), concerning the Hughes Helicopter 7.62 mm Chain Gun. The BRL agreed to perform a kinetic evaluation of the gun and collect motor characteristic data for their use in completing and evaluating a computer model of the chain gun.

A chain gun, SN EX 008 was received. Testing was begun to determine start-up loads for various initial positions within the firing cycle. Initially a Technipower Model LA 80-25 regulated power supply was used to power the gun. However, throughout the majority of the testing two 12 volt automotive batteries in series were used to more closely simulate the gun's use in a tank. Later, a Hughes Helicopter firing control box was delivered. This box stops the gun in the same position in the gun's firing cycle regardless of where it is when the trigger is released. Therefore, only one start up position is of importance. This position is on the rearward stroke of the bolt carrier just as the striker springs make contact for compression. Figure 1 shows the chain gun and its major components.

II. TEST PLAN AND SETUP

In order to determine the loads on the motor, the input voltage and current to the motor were monitored. Figure 2 shows a schematic of this setup. Time histories of current and voltage were calibrated and stored using IBD's Ballistic Data Acquisition System (BALDAS). Bolt carrier and hand crank position information were also stored with BALDAS.

Time information from the position data was used to determine the average motor speed over the twelve revolutions it makes per gun cycle. Motor speed was used to determine the work done by the motor from the power information.

Two methods were used to monitor position. An Optron, which is an electro-optical device, was used to track the motion of the bolt carrier. This required that the bolt carrier be exposed. The second method provided position information without exposing the bolt carrier. This method consisted of attaching a one-turn potentiometer to the hand crank shaft which generated a saw tooth curve for each cycle of gun operation. The curve was then calibrated to provide the angular position of the hand crank. Because the moving components of the gun are keyed together, knowing the position of any one component will reveal the position of all the other components. Figures 3 and 4 show bolt-carrier position and hand crank angle with respect to operations of the gun.

By removing various components from the gun and comparing loads on the motor with and without a particular component, the load required to

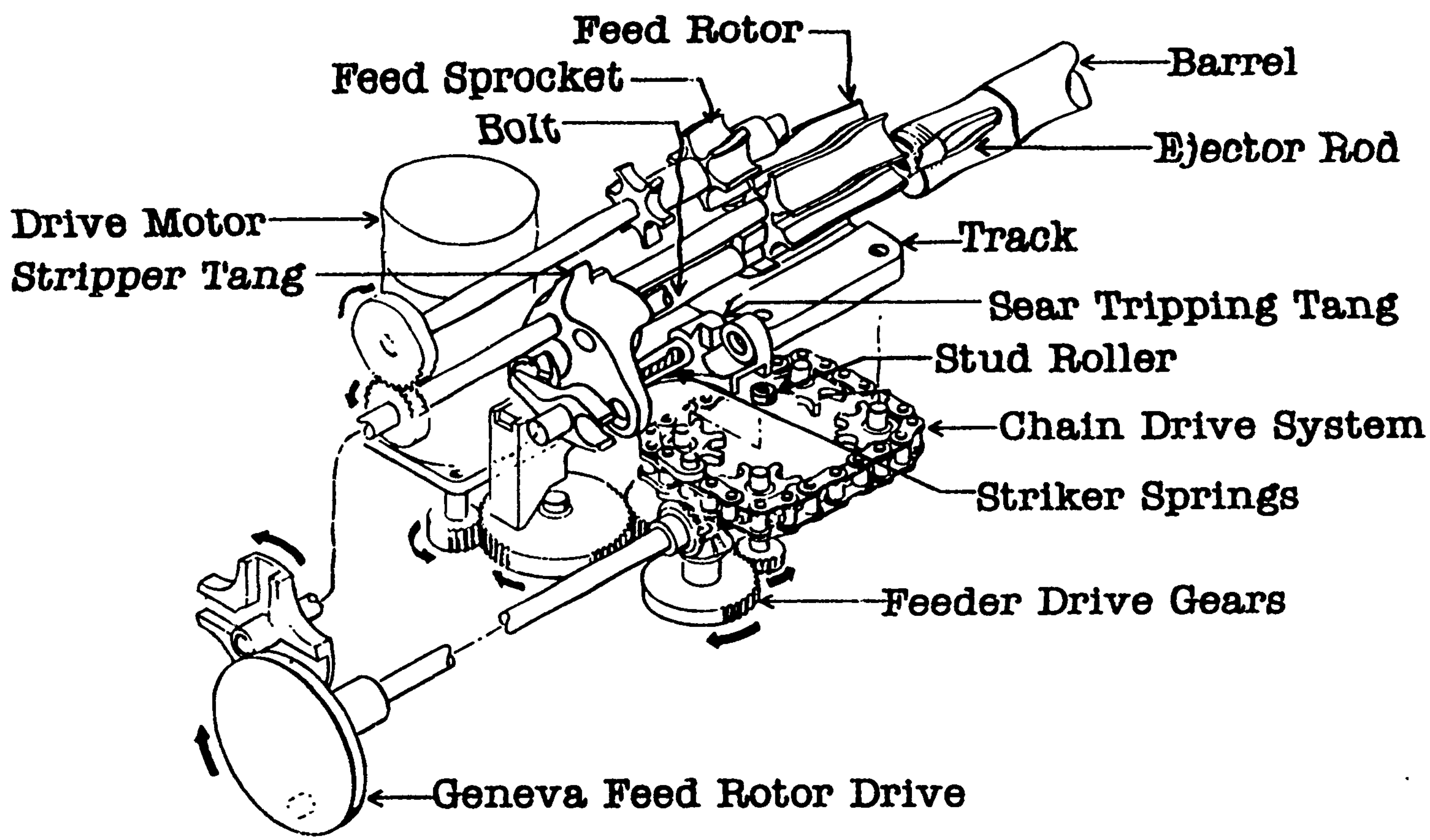


Figure 1. 7.62 mm Chain Gun and Components

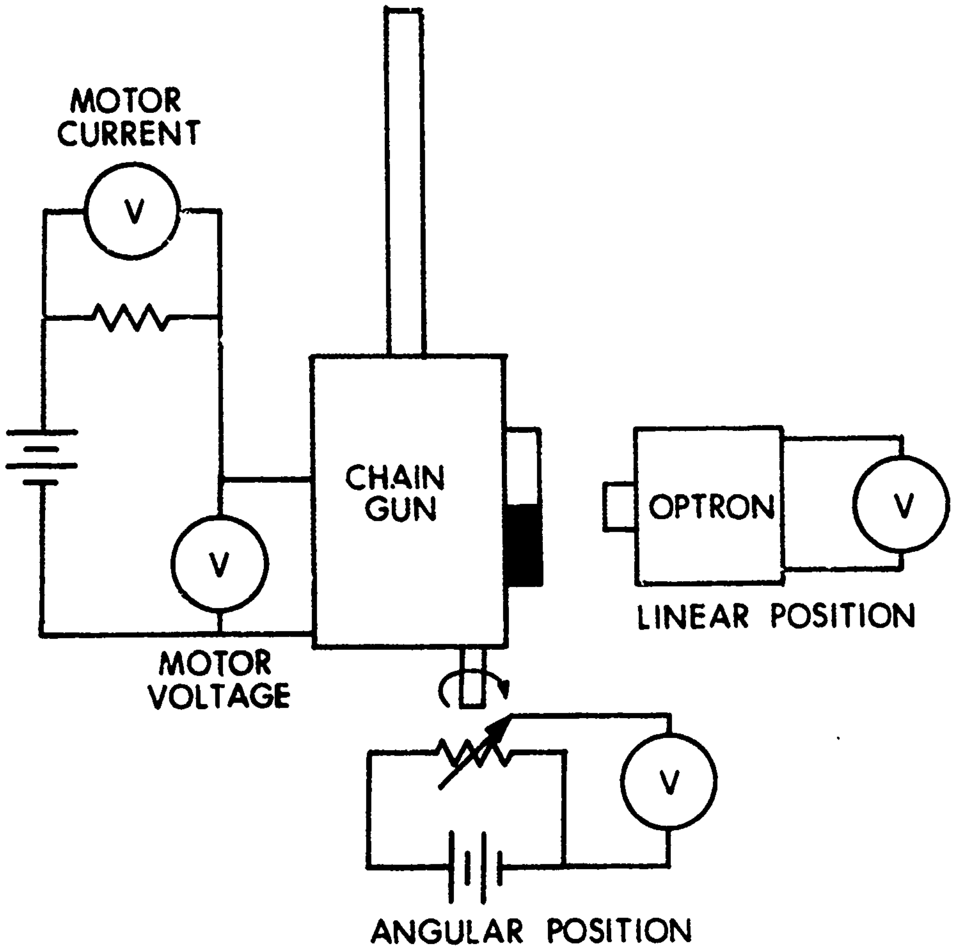


Figure 2. Test Setup Schematic

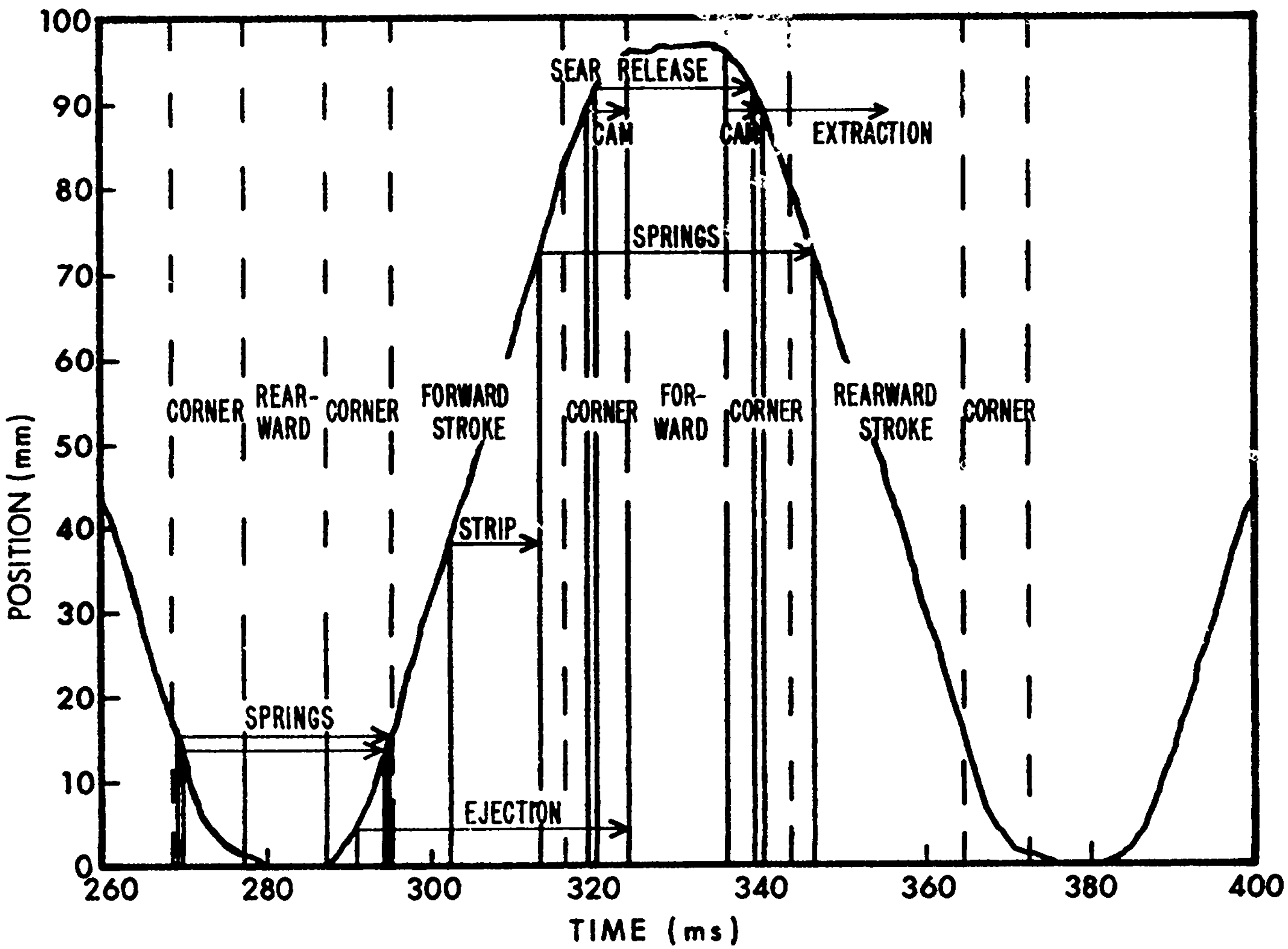


Figure 3. Bolt-carrier Position

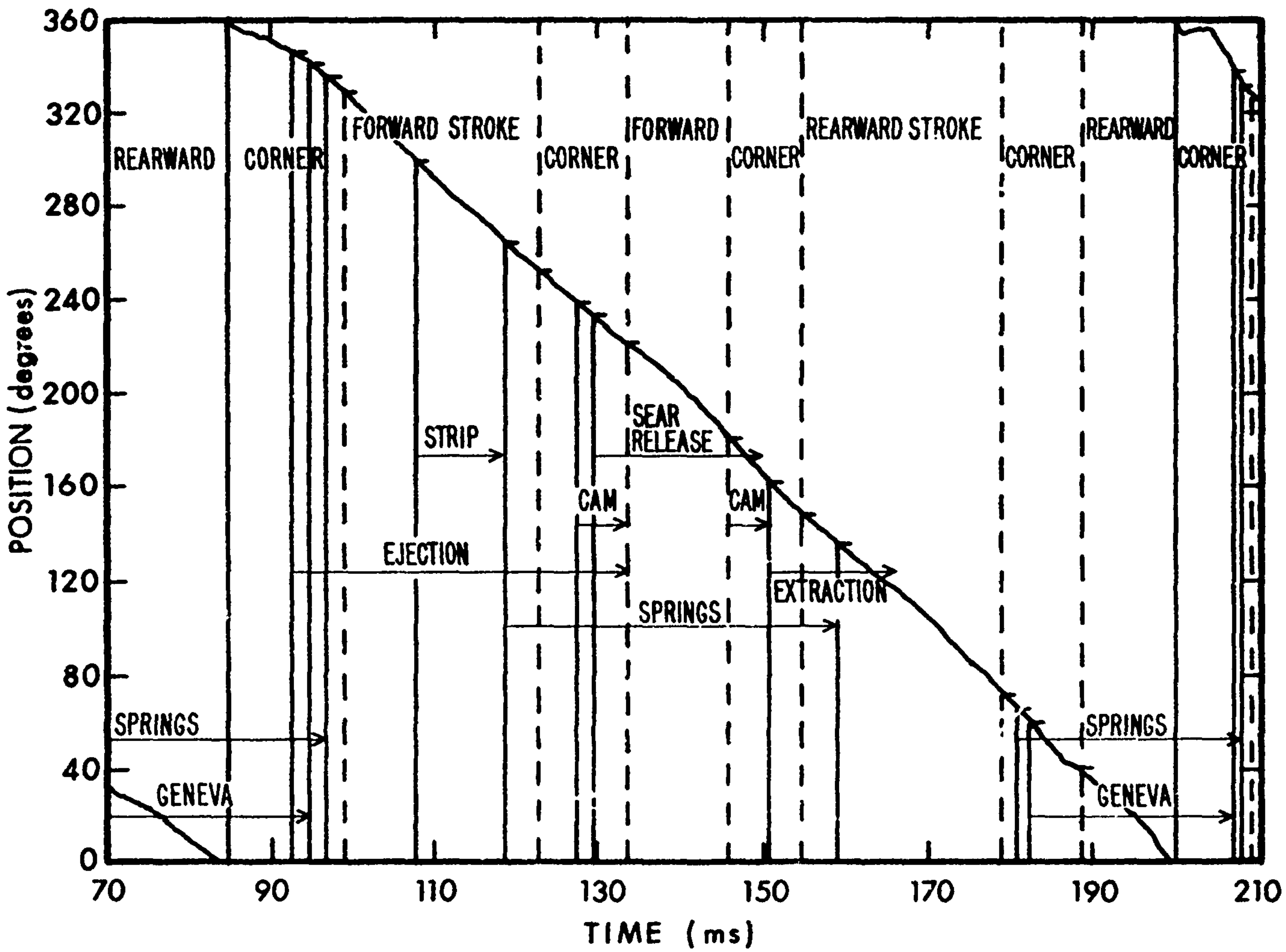


Figure 4. Angular Position of Hand Crank

function that component was determined. The following load components were evaluated:

- Effect of linked rounds;
- Effect of linked dummies;
- Load to release the striker;
- Load of striker springs;
- Effect of bolt-carrier mass;
- Load of feeder operation (geneva, feed sprocket and rotor);
- Load of chain

Additionally, the loads of ejecting, chambering, extracting, and stripping were determined from cycles within the firing data.

Muzzle velocity and dispersion data were also gathered. Muzzle velocity was determined using TSI Universal Counters triggered by five lumiline screens placed at known distances from each other and the muzzle. Muzzle velocity was extrapolated using a least squares fit through the velocities calculated between the screens. Dispersion was determined from a ten-round burst fired down a nominally 18 meter range into a cardboard target.

III. RESULTS

Initial testing using the regulated power supply and the automotive batteries with 14 gauge wire provided less power than the Hughes control box and cable as shown in Table 1. One attempt to start the gun using the 14 gauge wire and 24 volt battery system failed. The bolt was positioned against the striker spring to provide a maximum start up load. The current reached 28 amperes and the voltage dropped to 11 volts yielding 300 watts which would not turn the motor against the load. Replacing this wire with 12 gauge wire increased the voltage at the motor from 19 volts to 22 volts and the running current from 13 to 16 amperes. At this time a Hughes control box and cable were acquired, eliminating the effect of cabling on the test. The Hughes cable is 10 gauge. The motor running voltage and current were increased to 23 volts and 20 amperes, respectively.

Starting the gun with rounds in the feeder sprocket using the Hughes control box required 1050 watts, with a peak current of 60 amperes. Energy consumption of the individual components are shown in Figure 5. The positions at which these loads are encountered are shown in Figure 6.

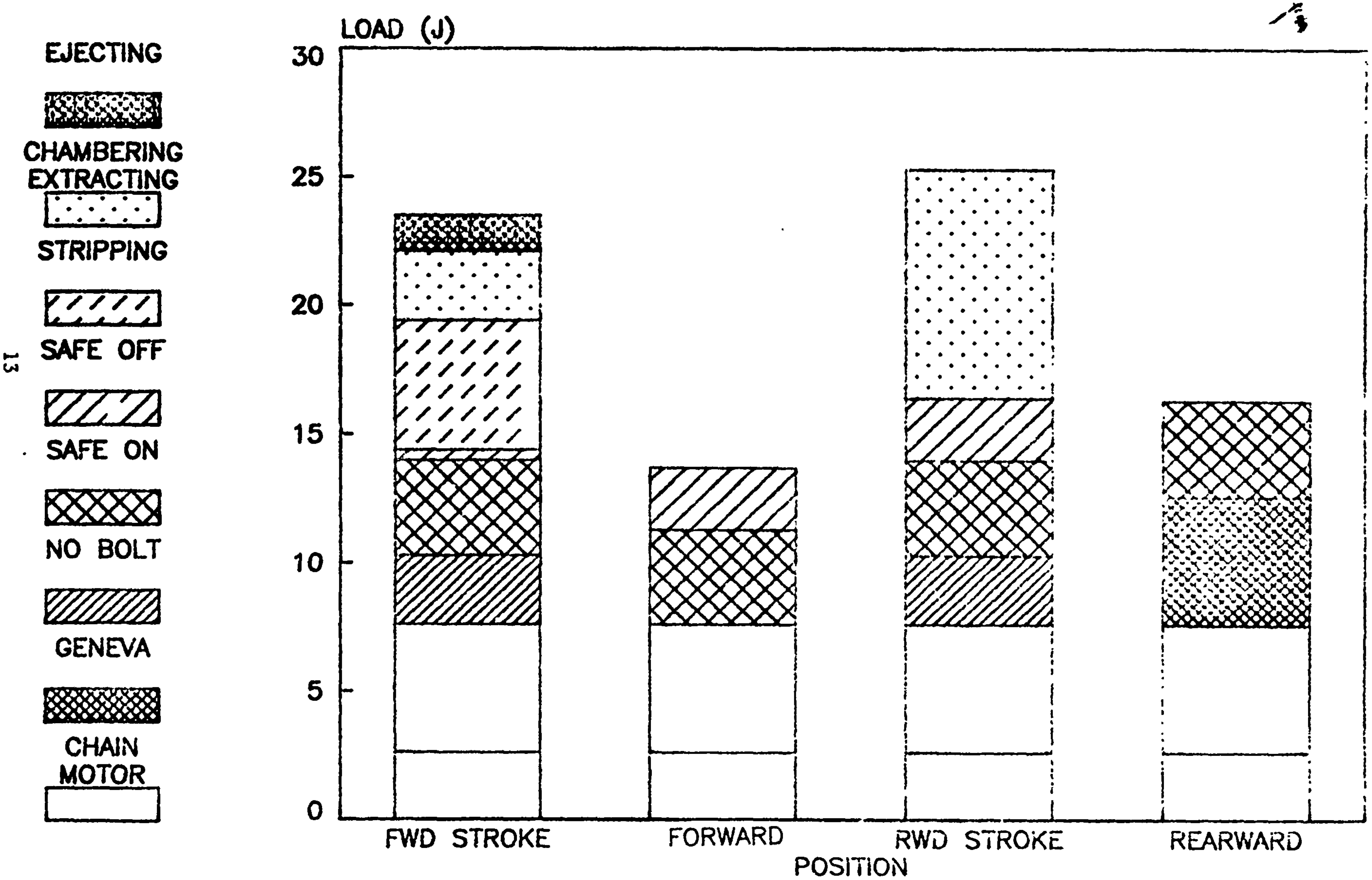


Figure 5. Component Loading of Chain Gun

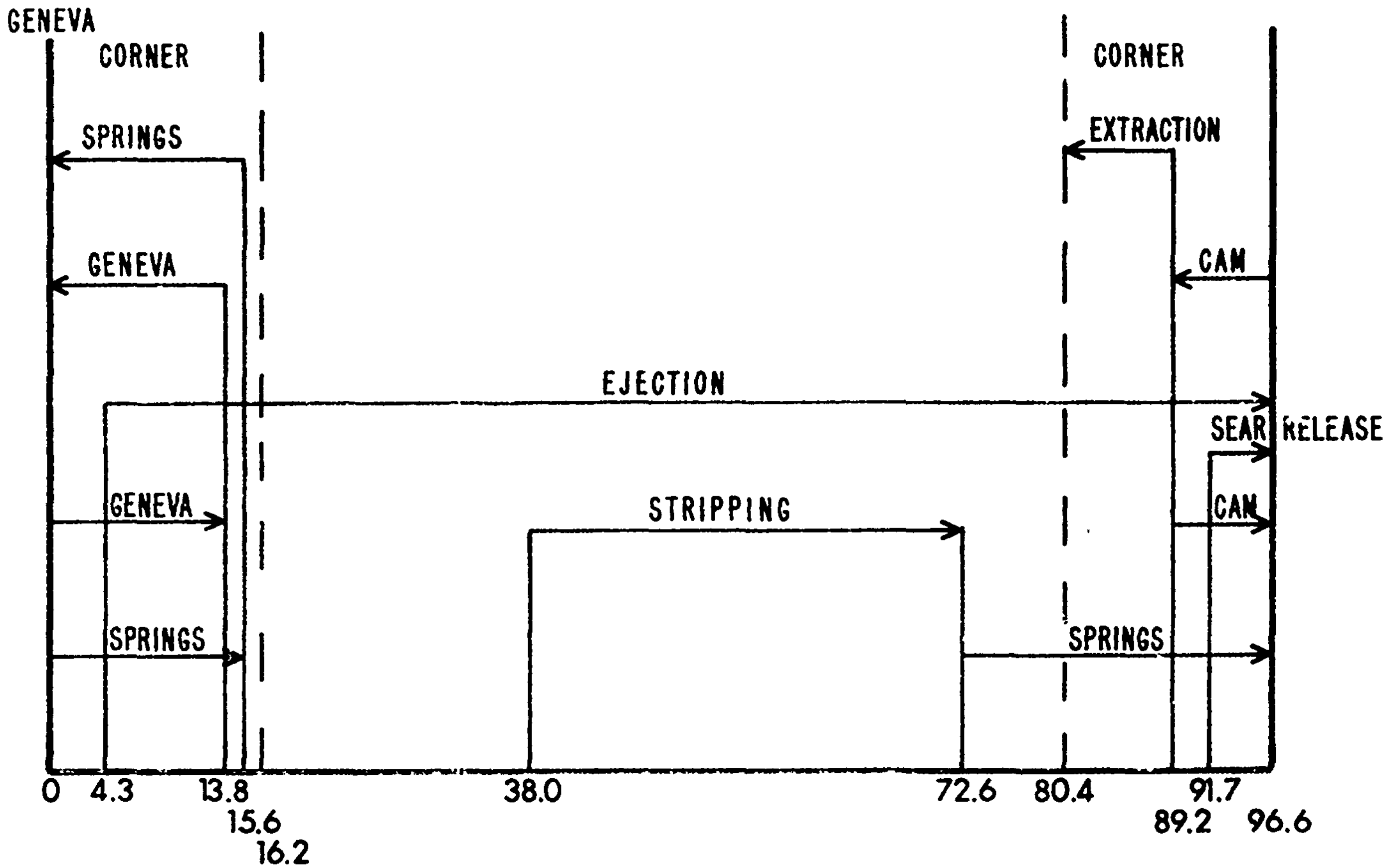


Figure 6. Bolt-carrier Position of Loads

TABLE 1. EFFECTS OF CABLING

CONDITION	P_{peak} (WATTS)	C_{peak} (AMPS)	$C_{running}$ (AMPS)	V (VOLTS)	N (RPM)
14 Gauge Wire Power Supply	300	26	11	18	5760
14 Gauge Wire Batteries	290	24	12	19	5900
12 Gauge Wire Batteries	640	43	17	22	6860
Hughes Cable (10 Gauge) Batteries	1050	60	19	24	7580

Typical data output is shown in Figures 7 through 13. Figure 7 shows the voltage drop as the motor starts and the running voltage for steady state operation. Motor current is shown in Figure 8. Current peaks as the motor begins to turn and then drops to normal operating levels. Power and position, shown in Figure 9, give the required information to determine work done by the motor. Figures 10 and 11, safe on and safe off, are used to determine the power required to operate the sear safety assembly. The 165 Hz filter level used to simplify data reduction was determined experimentally to reduce noise in the steady state operation of the gun with little effect on the magnitude of current or voltage values. This filtration does effect the magnitude of start up peak loading and therefore was not used when determining these values. In cycle data, stripping and chambering is shown in Figures 12 and 13. Figure 13, Chambering includes the effects of extraction.

Loads on the stud roller were determined from the difference between the applied torque and the torque required to drive the chain and geneva gear. Because the roller cannot support a load in the "Y" direction, as shown in Figure 14, torque drops off when the bolt-carrier is in the rearward or forward positions. Torque, when the bolt-carrier is in these positions, is governed by the relationship of $T = \mu rL$ where T equals torque, r is the moment arm, L is the load applied against the roller, and μ is a friction coefficient. When the stud roller is in the forward or rearward strokes the friction coefficient, μ, is omitted. The loads on the roller are shown in Figure 15. Calculations of these loads are presented in Appendix B.

The striker spring assembly was calibrated using an Instron testing machine. The spring constant for the assembly is 1629 N/m. The

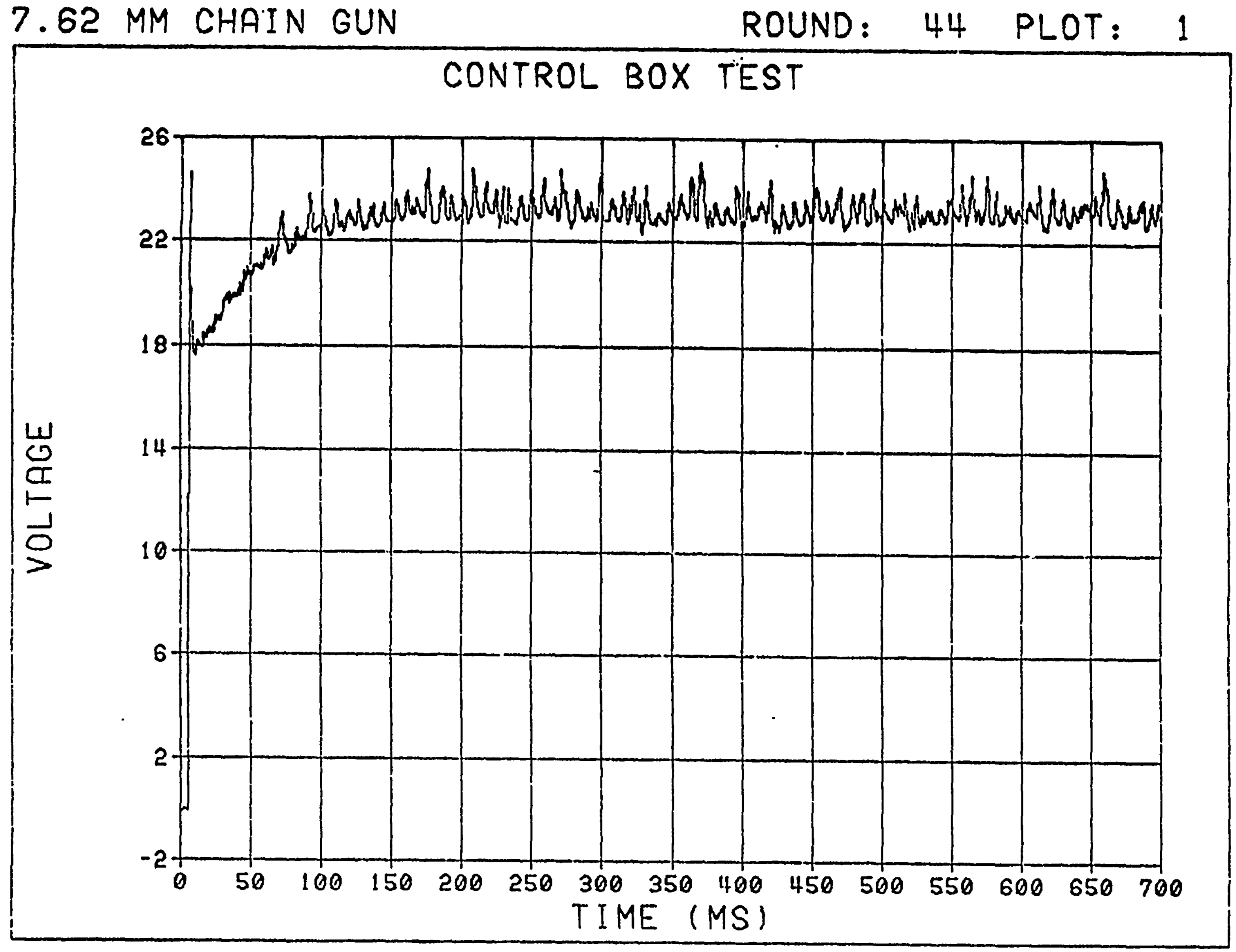


Figure 7. Motor Voltage

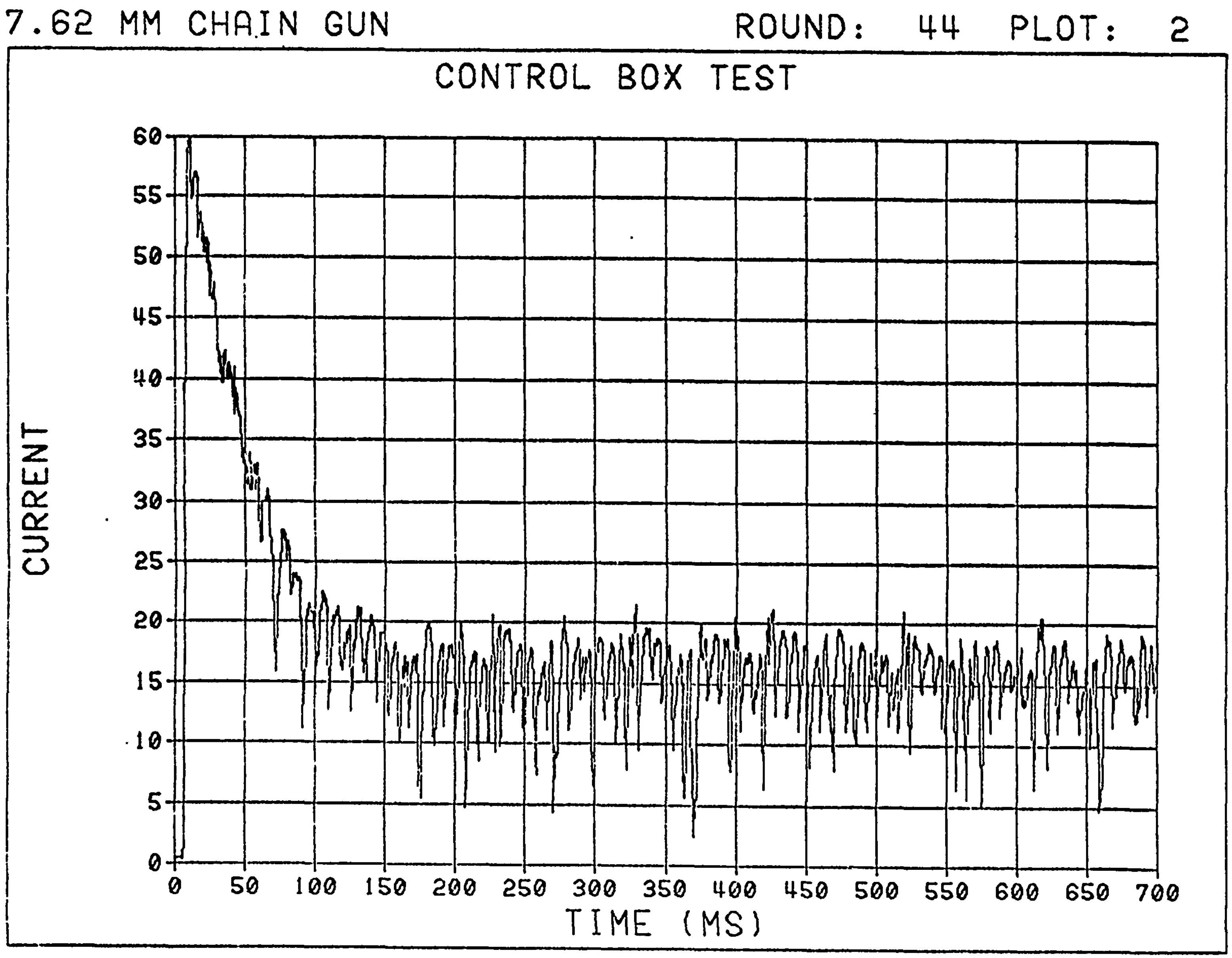


Figure 8. Motor Current

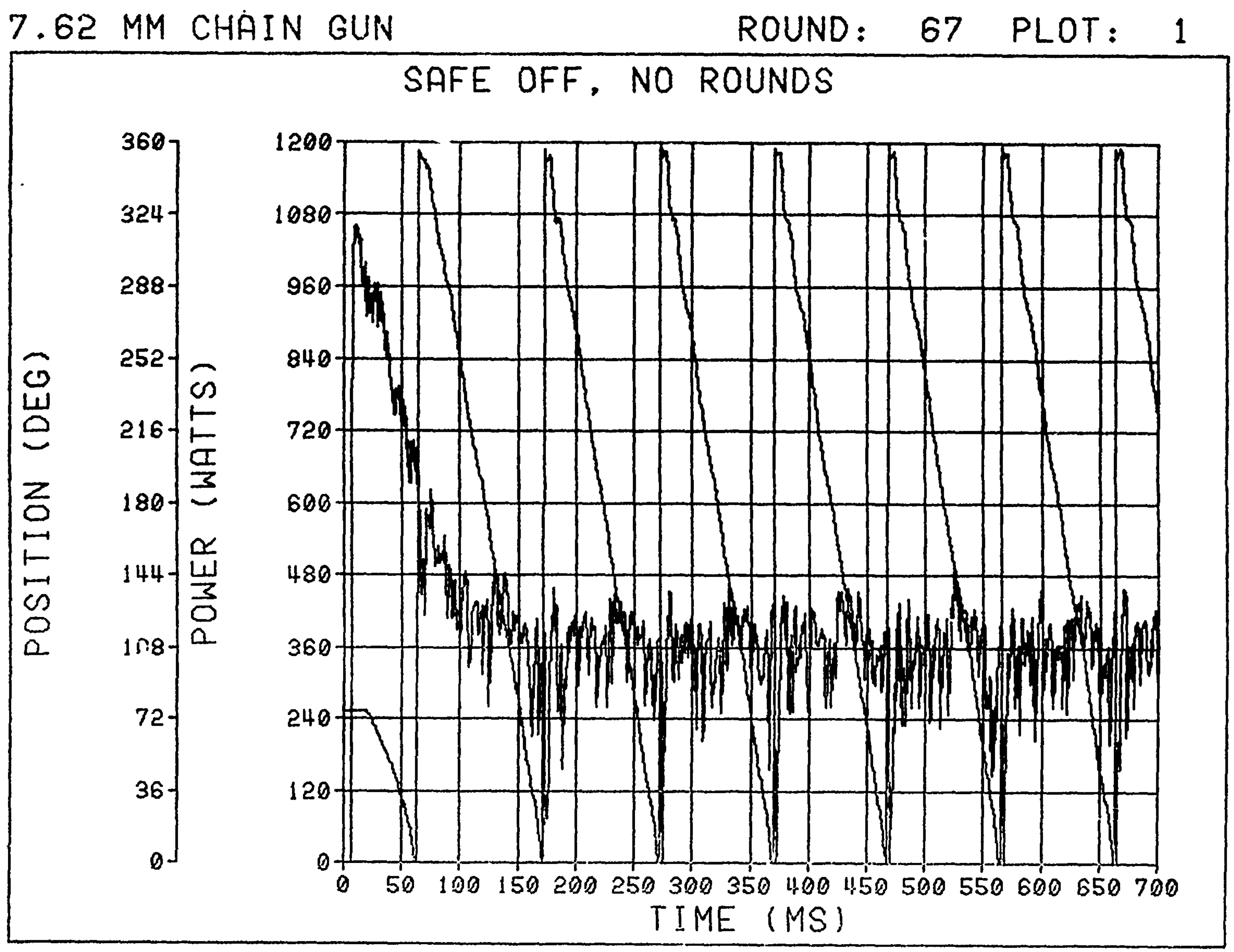


Figure 9. Power and Position

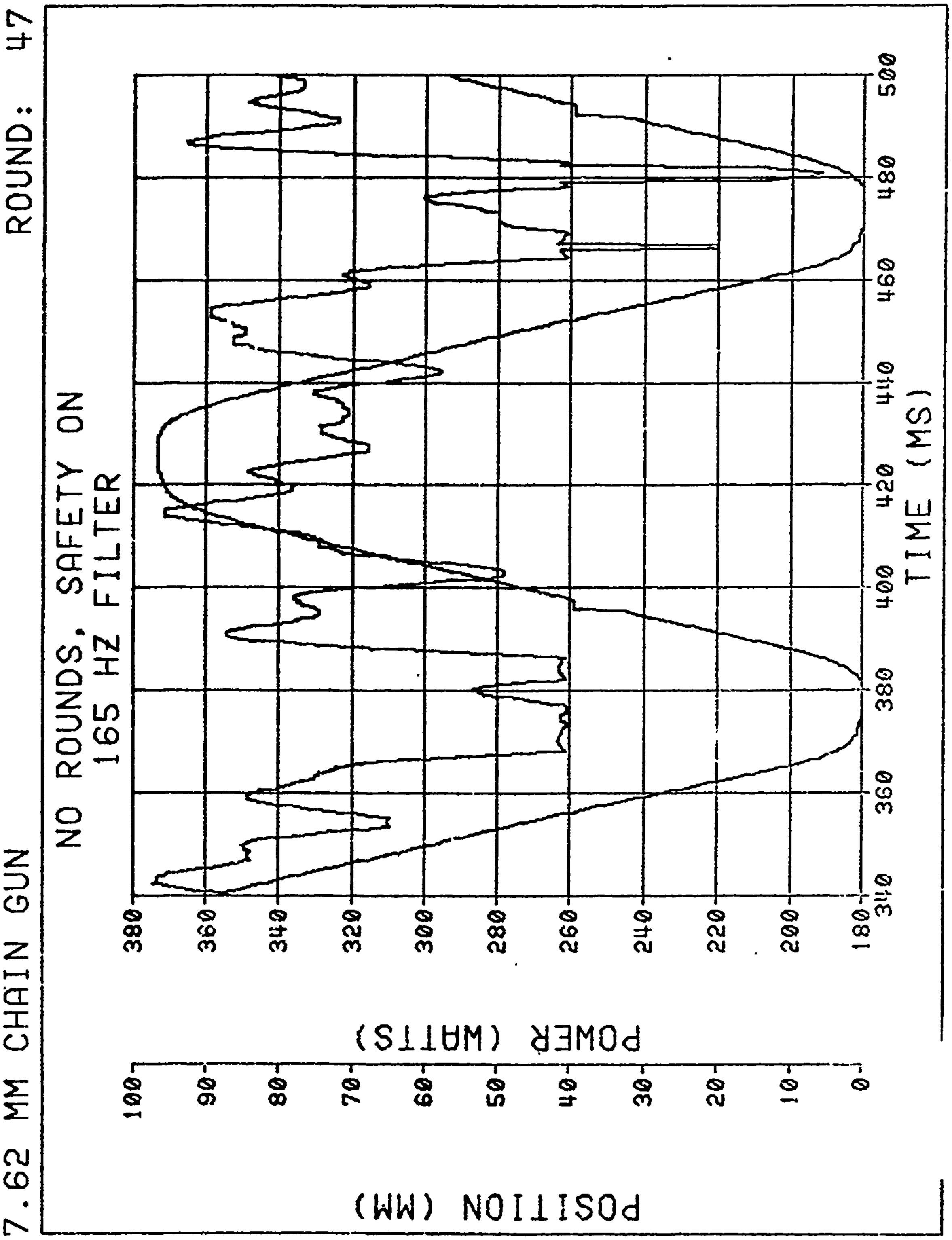


Figure 10. Power with Safe On

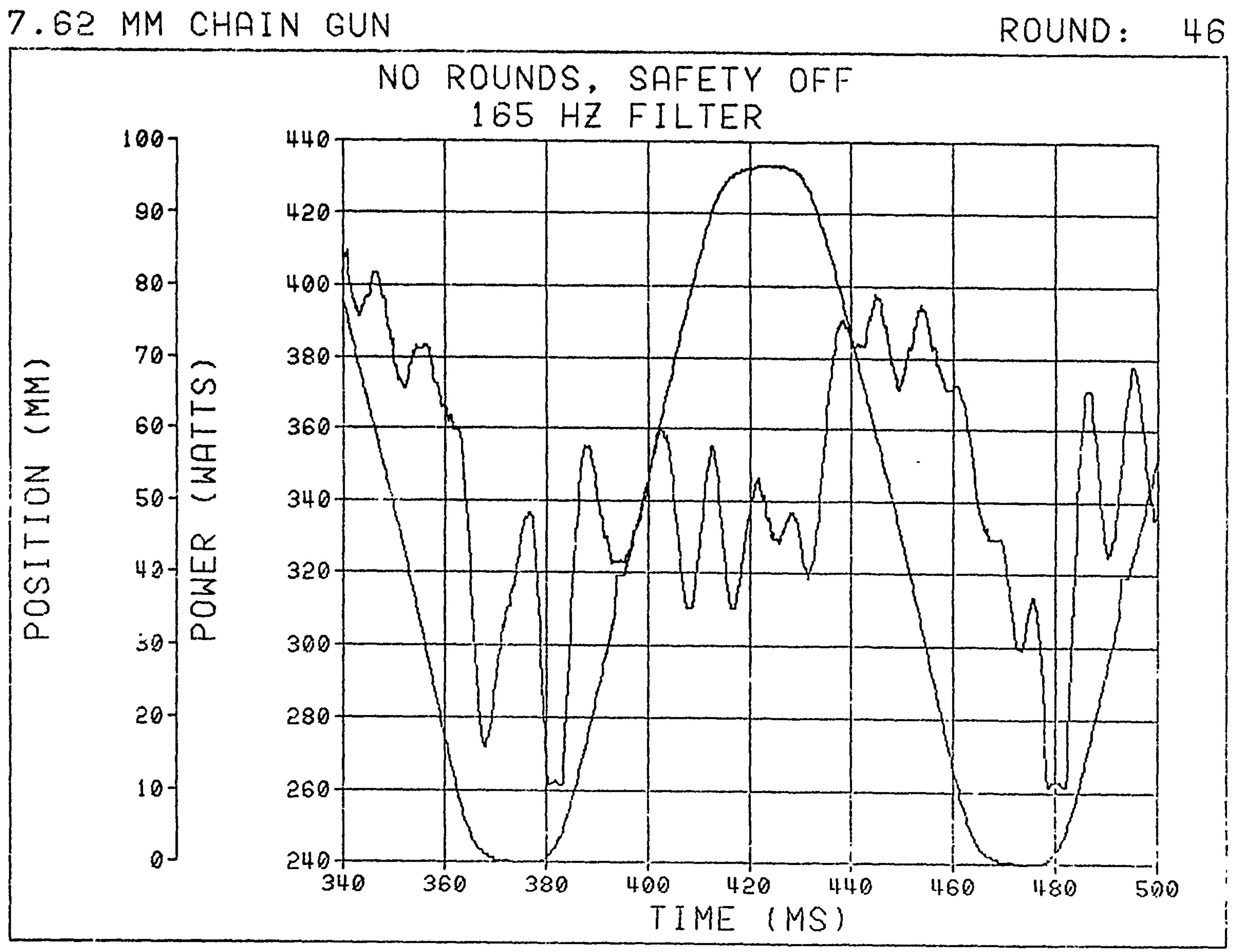


Figure 11. Power with Safe Off

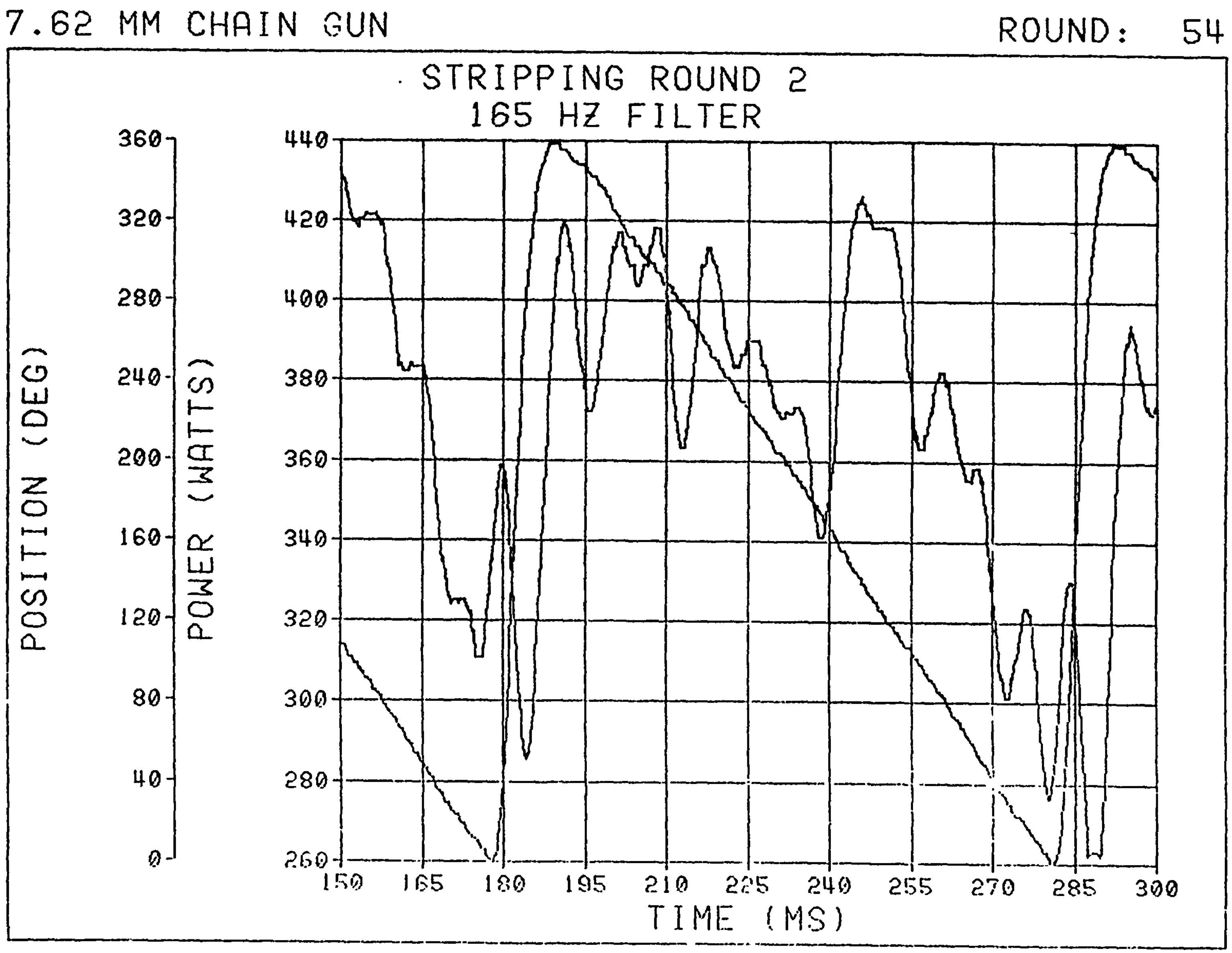


Figure 12. Power Stripping

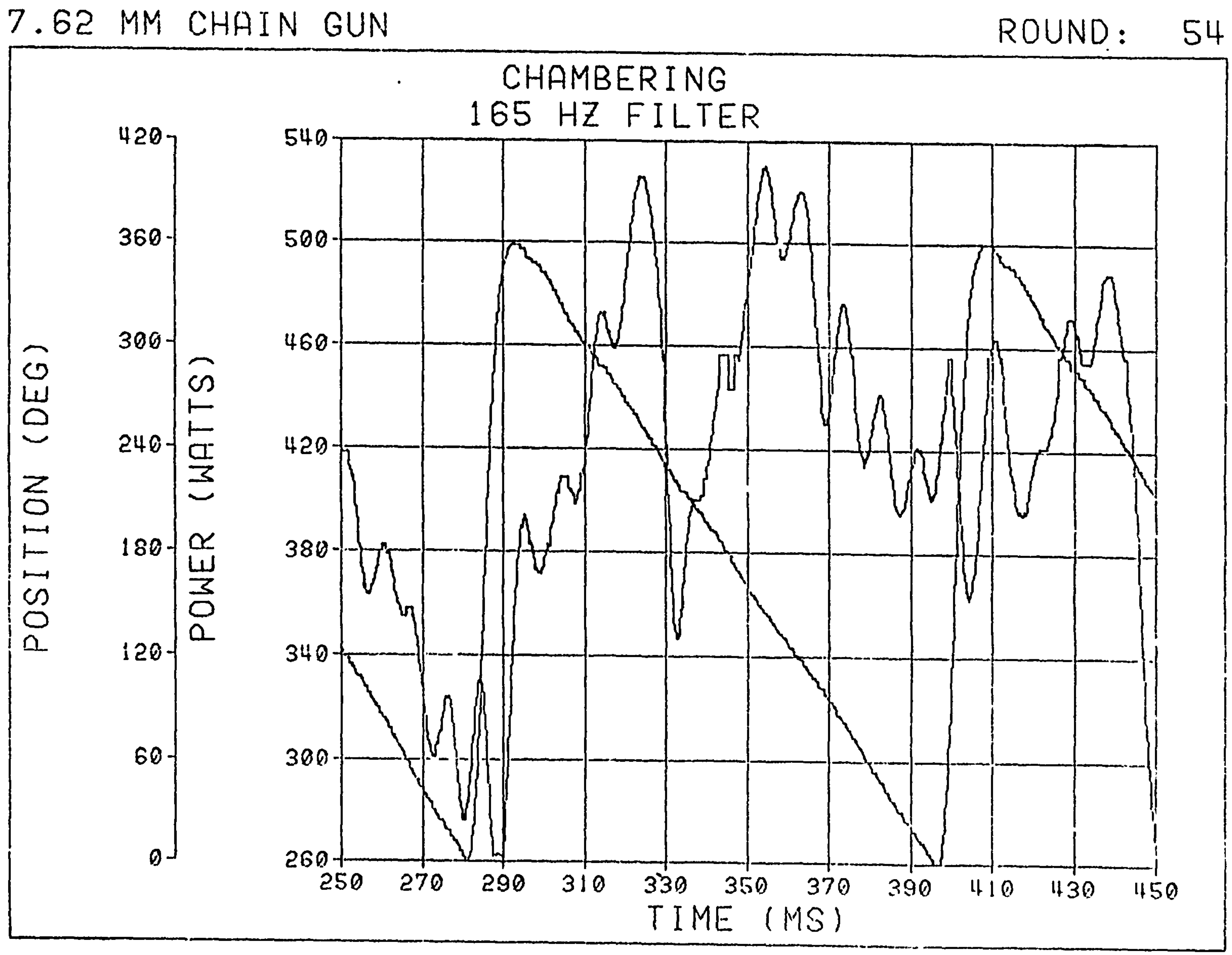
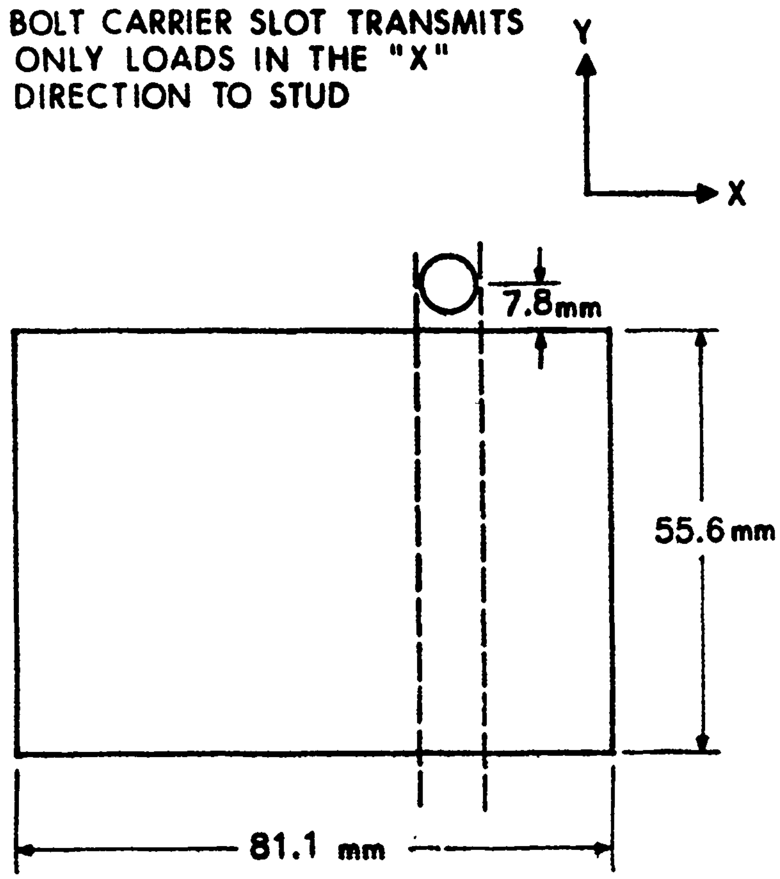


Figure 13. Power Chambering



Figur· 14. Stud Roller/Bolt-carrier Interface

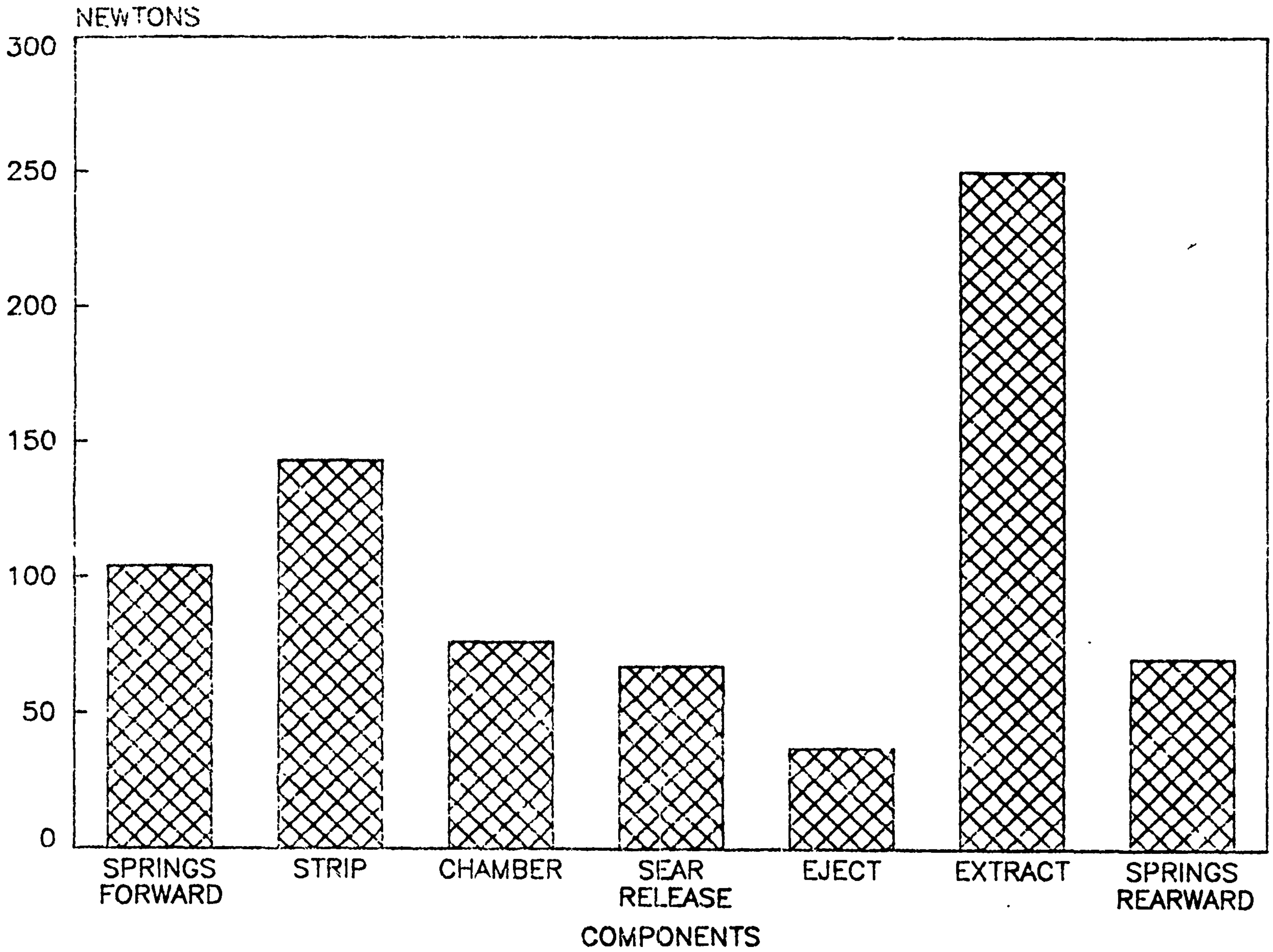


Figure 15. Stud Roller Loads

assembly has a preload of 53.4 N. In the forward position the springs are compressed to provide a load of 96.5 N. This corresponds well with the 104 N load on the roller found experimentally. The 104 N load also includes the effects of the extra mass of the bolt, locking and unlocking, interaction with the sear cam, and frictional losses as well as experimental error.

A newer version of the chain gun with a shunt field motor, rather than a permanent magnet motor as in the former version, required more power. The gun, when used with automotive batteries, used 2300 watts to start, drawing 101 amperes. Firing rounds, it drew 102 amperes to start and peaked at 25 amperes running as shown in Figure 16. It fired at a rate of 600 shots per minute (SPM). Firing with the new Hughes firing control box and power supply, which has a current limiting feature, the gun drew 47 amperes at start up which required 560 watts. It ran with a peak current of 19 amperes at a rate of 510 SPM as shown in Figure 17.

Firing a ten-round burst of ball ammunition at a target 19.0 m away yielded a maximum spread of 28.6 mm. This dispersion, shown in Figure 18, is 1.5 mil, σ_H is 5.17 mm and σ_V is 4.60 mm.

Muzzle velocity firing ball ammunition was found to be 890 m/sec as shown in Figure 19. σ was equal to 4.83 m/sec.

IV. CONCLUSIONS

The effect of the cable is of considerable importance because of the large current drawn at start up. Losses through the cable should be minimized by using large gauge cabling and reducing the cable length where possible.

Start up requires the greatest amount of power, drawing up to 60 amperes. The gun operating at 24 volts draws 22 amperes.

The stud roller carries loads of up to 497 Newtons.

The gun with the control box stops within 100 msec of trigger release, after extracting the fired case. Without the control box, the gun stops in a minimum of 150 msec and may take about 300 msec to stop. The gun will stop on either the forward or rearward stroke.

The new shunt wound motor draws 102 amperes from an automotive battery power supply and runs at 600 SPM. Operating with the Hughes power supply, starting current is 49 amperes and the gun operates at 510 SPM.

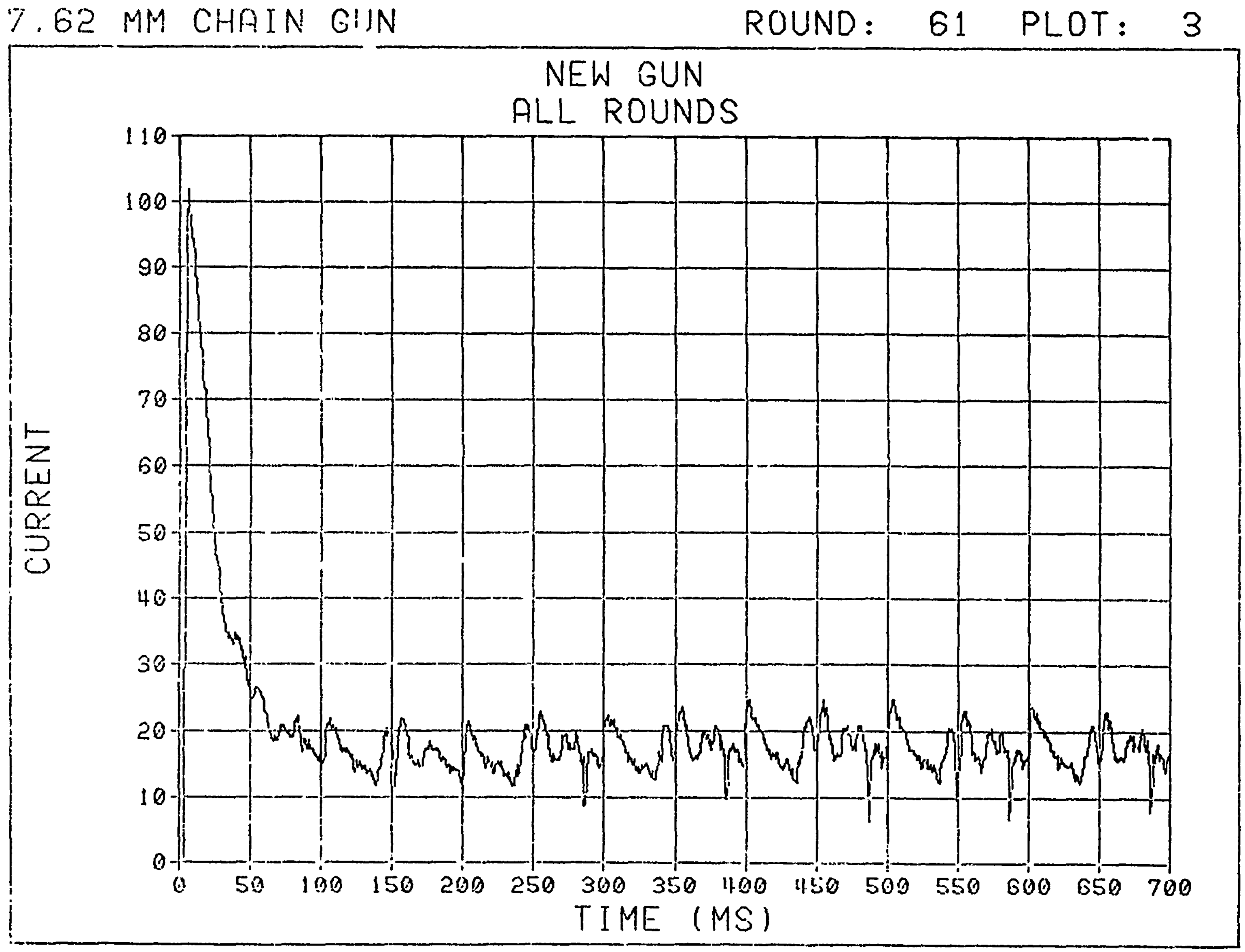


Figure 16. New Gun Current (Shunt Wound Motor)

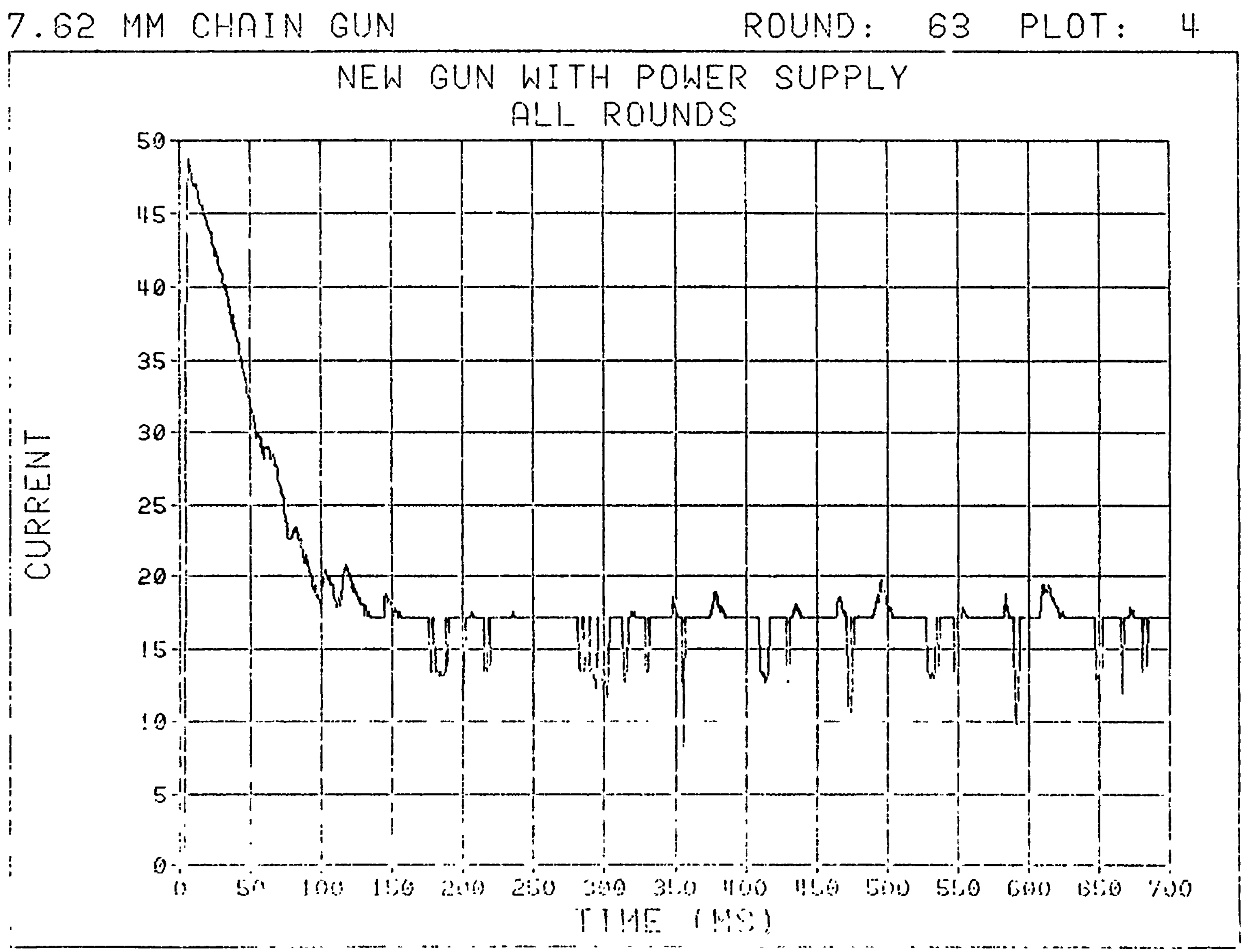


Figure 17. New Gun with Power Supply Current (Shunt Wound Motor)

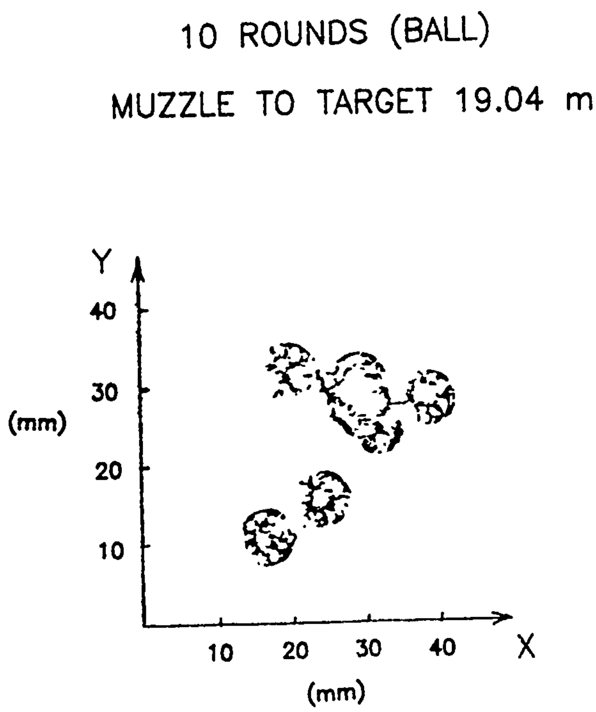


Figure 18. Dispersion

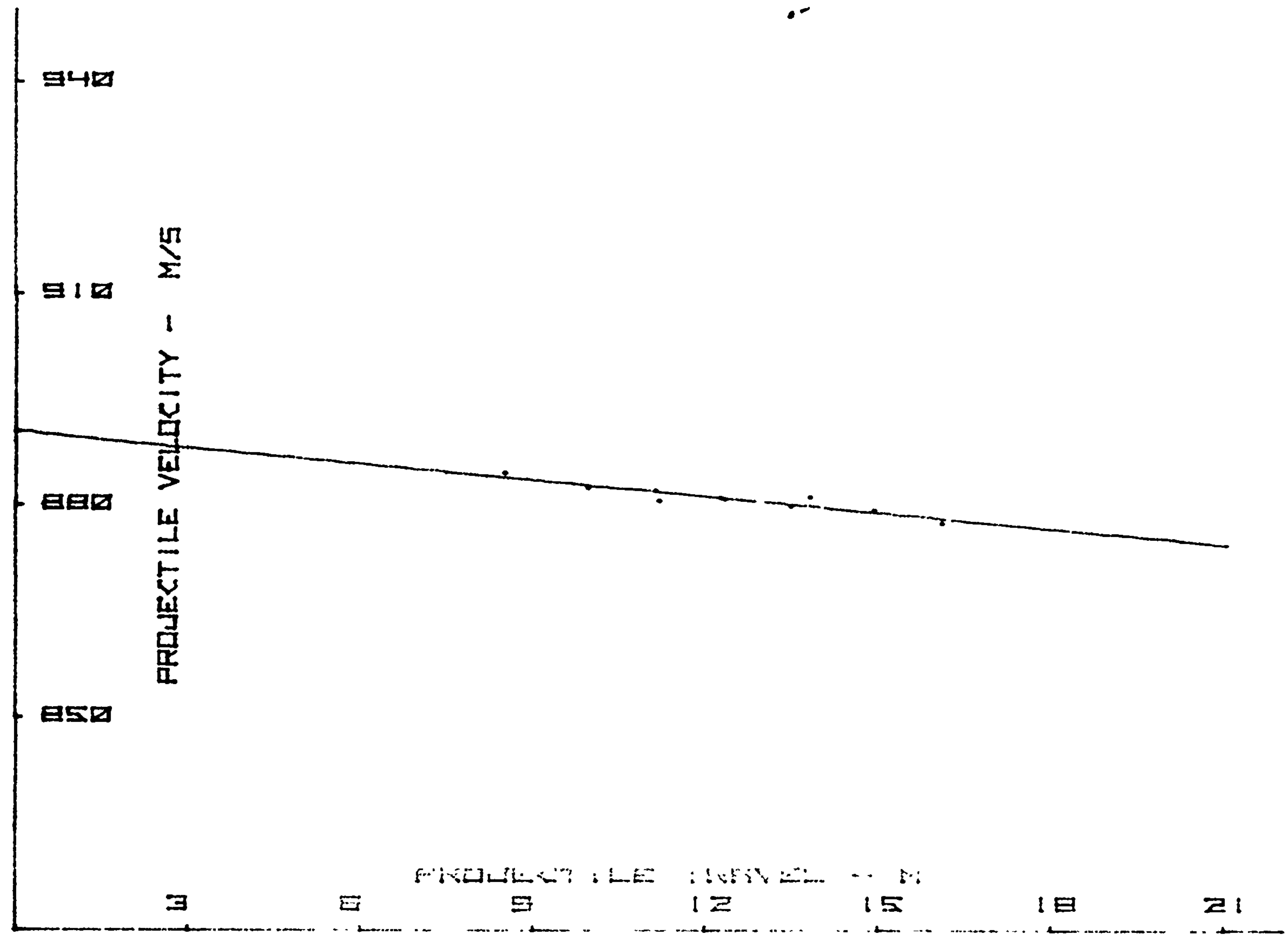


Figure 19. Muzzle Velocity

APPENDIX A

MANIPULATED DATA

APPENDIX A

MANIPULATED DATA

12 Gauge Wire

CONDITION	P (Watts)	t (msec)	E' (J/min)	t_1 (Γ/min)	[illegible]
CHAIN AND GENEVA	210	87	12600	1317	9 6
SAFE ON	320	102	19240	1123	17 1
SAFE OFF	350	105	21000	1091	19 3

P - Power of operation

t - Period of one cycle

E' - Power

t_1 = Speed of Motor (radians/min).

E - Energy Required

PRECEDING PAGE BLANK-NOT FILMED

GUN WITH HUGHES CONTROL BOX

CONDITION	P (Watts)	t (msec)	E' (J/min)	t_1 (Γ/min)	E (J)	*E_{Comp} (J)
MOTOR	75	---	4500	1719	2.6	2.6
CHAIN	180	80	10800	1432	7.6	5.0
GENEVA	265	86	15900	1332	11.9	4.3
NO BOLT	310	90	18600	1273	14.6	2.7
SAFE ON	360	97	21600	1181	18.3	3.7
SAFE OFF FORWARD	360	99	21600	1157	18.7	0.4
REARWARD	400	99	24000	1157	20.7	2.4
DUMMIES CHAMBERING AND STRIPPING	430	107	25800	1071	24.1	5.4
EXTRACTING	420	107	25200	1071	23.6	2.9
DUMMIES CHAMBERING AND STRIPPING	420	104	25200	1102	22.9	4.2
EXTRACTING	430	104	25800	1102	23.5	2.8
ROUNDS STRIPPING	430	105	26600	1091	24.4	5.7
CHAMBERING	460	109	27600	1051	26.3	1.9
EXTRACTING	470	109	28200	1051	26.8	6.1
EXTRACTING	510	112	30600	1023	30.0	9.2
EJECTING	450	112	27000	1023	26.4	0.1
STRIPPING	430	103	26600	1113	23.2	4.5
CHAMBERING	450	108	27000	1061	25.5	2.3
EXTRACTING	460	108	27600	1061	26.0	5.3
EXTRACTING	540	112	32400	1023	31.7	11.0
EJECTING	500	112	30000	1023	29.3	3.8
STRIPPING	440	103	26400	1113	23.7	5.0
CHAMBERING	480	110	28800	1042	27.7	3.9
EXTRACTING	530	110	31800	1042	30.5	9.8
EXTRACTING	550	113	33000	1014	32.5	11.8
EJECTING	470	113	28200	1014	27.8	0.1

*E_{Comp} - Energy required to operate that component.

NEW GUN (SHUNT WOUND MOTOR)

Condition	P (Watts)	t (msec)	L (J/min)	t_1 (r/min)	E (J)
CHAIN	165	88.5	8615	1295	6.6
SAFE ON	500	94.5	26100	1213	21.6
SAFE OFF	530	95	27670	1206	22.9
DUMMIES STRIPPING	530	99	29760	1158	23.9
DUMMIES "FIRING"	570	99	29880	1158	25.8
ROUNDS STRIPPING	590	100.5	30800	1140	27.0
ROUND FIRING	600	100.5	31320	1140	27.5
W/POWER SUPPLY SAFE ON	350	97.5	18270	1175	15.6
W/POWER SUPPLY ROUNDS	360	118.5	18790	967	19.4
W/POWER SUPPLY CHAIN	165	88.5	8610	1295	6.6

APPENDIX B

STUD ROLLER LOAD CALCULATIONS

PRECEDING PAGE BLANK-NOT FILMED

APPENDIX B

STUD ROLLER LOAD CALCULATIONS

$L = T/\Gamma$, L = Load on Roller, T = Torque,

Γ = moment arm

$\Gamma = 55.6/2 + 7.8$ mm, Roller on side of sprocket support

$\Gamma = .0356$ m

LOAD OF SPRINGS (FORWARD) (SAFE ON - NO BOLT)

$L = (18.3 - 14.6)/.0356$

$L = 104$ N

LOAD OF STRIKER REARWARD)
(SPRINGS: 290 w @ 97 msec, NO BOLT 260 w @ 90 msec)

$L = (14.7 - 12.2)/.0356$

$L = 70$ N

LOAD OF STRIKER RELEASE (SAFE OFF - SAFE ON)

$L = (20.7 - 18.3)/.0356$

$L = 67$ N

LOAD OF STRIPPING (STRIPPING - SAFE OFF)

$L = (23.8 - 18.7)/.0356$

$L = 143$ N

LOAD OF CHAMBERING (CHAMBERING - STRIPPING)

$L = (26.5 - 23.8)/.0356$

$L = 76$ N

LOAD OF EXTRACTION (EXTRACTION - SAFE OFF REARWARD)

$L = (29.6 - 20.7)/.0356$

$L = 250$ N

LOAD OF EJECTION (EJECTION - CHAMBERING)

$L = (27.8 - 26.5)/.0356$

$L = 37$ N

TOTAL LOADS ON ROLLER

LOAD = (WORK DONE TOTAL - WORK NOT DONE THROUGH ROLLER)/.0356

FORWARD STROKE

L = (23.5 - 7.6)/.0356

L = 447 N

REARWARD STROKE

L = (25.3 - 7.6)/.0355

L = 497 N

APPENDIX C

STRIKER SPRING ASSEMBLY CALIBRATION

APPENDIX C

STRIKER SPRING ASSEMBLY CALIBRATION

0 COMPRESSION 12.0 LB (53.4 N)

.805 Inch (20.4 nn) COMPRESSION 19.5 LB (86.7 N)

SPRING RATE 9.3 LBS/IN + 12.0 LBS
(1628.7 N/n + 53.4 N)

IN USE PRELOAD

.12 Inch (3.0 nn) COMPRESSION
Yields 13.1 LB (58.3 N)

FOREWARD

1.04 Inch (26.4 nn) COMPRESSION
Yields 21.7 LB (96.5 N)

REARWARD

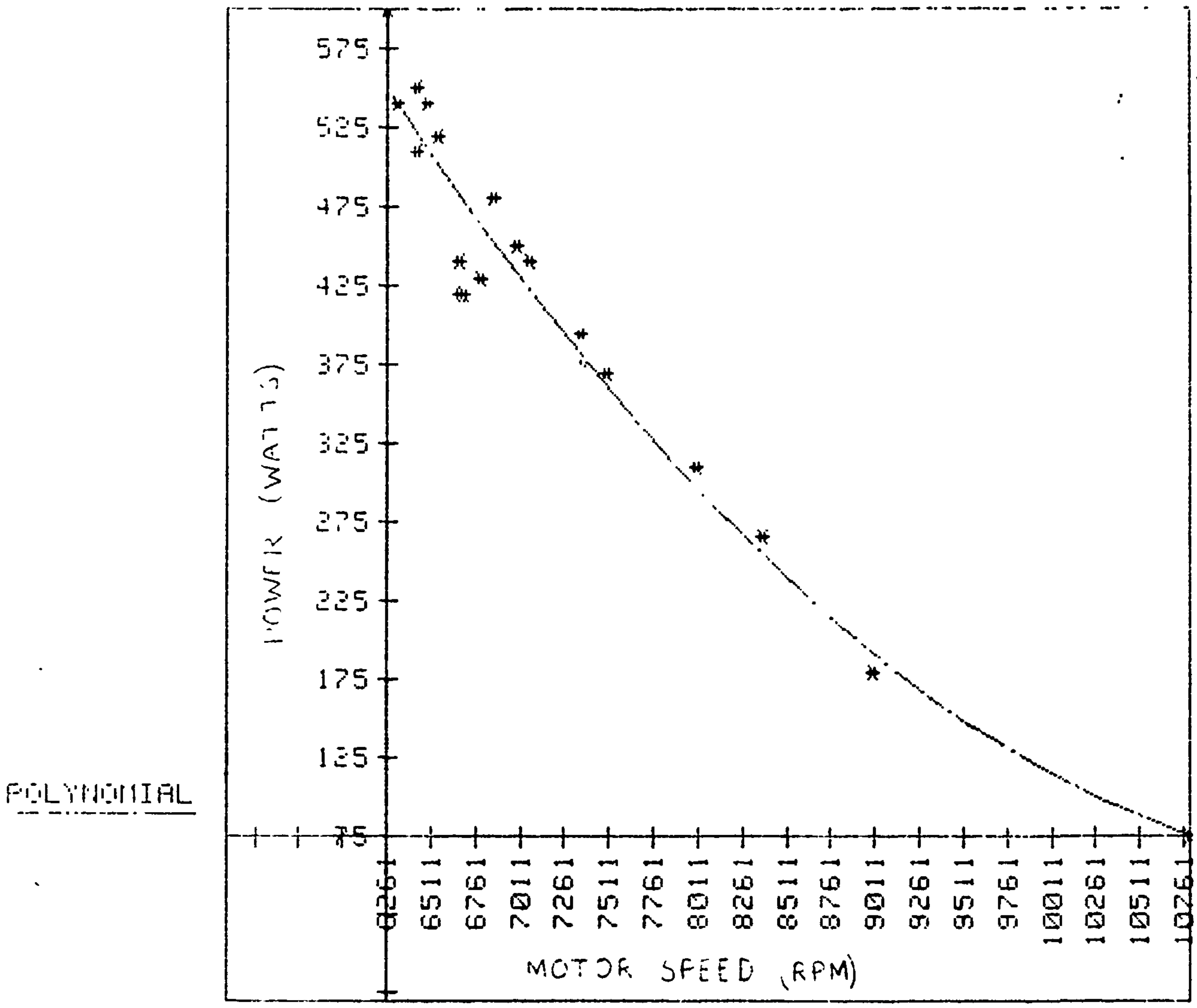
.56 Inch (14.2 nn) COMPRESSION
Yields 18.6 LB (82.6 N)

APPENDIX D

MOTOR DATA AND SPECIFICATIONS

APPENDIX D

MOTOR DATA AND SPECIFICATIONS



TACHTRONIC INSTRUMENTS DC MOTOR PART NO. 25DCMI 313

PRECEDING PAGE BLANK-NOT FILMED

DATA

Point #1:	X=9000	Y=180
Point #2:	X=8372	Y=265
Point #3:	X=8000	Y=310
Point #4:	X=7500	Y=370
Point #5:	X=7347	Y=395
Point #6:	X=6667	Y=420
Point #7:	X=6667	Y=440
Point #8:	X=6990	Y=450
Point #9:	X=6429	Y=550
Point #10:	X=6690	Y=420
Point #11:	X=6316	Y=540
Point #12:	X=6857	Y=480
Point #13:	X=6792	Y=430
Point #14:	X=6429	Y=510
Point #15:	X=6261	Y=600
Point #16:	X=7059	Y=440
Point #17:	X=6545	Y=520
Point #18:	X=6486	Y=540
Point #19:	X=10800	Y=75

POLYNOMIAL MODEL: Y=A(M)*X^M+A(M-1)*X^(M-1)+...+A(1)*X+A(0)

Coefficients:

A(0)=2193.665511

A(1)=-.354012359

A(2)=1.46219658000E-05

Source	Df	SS	MS	F
Regression	2	300435.535	150217.767	141.942
Residual	16	16932.886	1058.305	
Total	18	317368.421		

3/21/78

25DCM1313

Hughes 445-1611 Rev. C

FACTUAL DATA

Test or Environment	Specification Values	Spec/Para Method/Condition	Unit No. 103	Unit No. 104	Unit No. 105	Unit No.	Pass
Starting Current			3.8A	3.7	3.8		
No Load Speed @ 18V DC			7350 RPM	7400	7400		
21V DC			8600 RPM	8400	8800		
24V DC			9800 RPM	10000	10100		
Load Speed @ 23.8V (45	oz in)		6500 RPM	6400	6600		
23.4V (90	oz in)		4300 RPM	4200	4400		
Stall Torque @ 22.5V			172 oz in	172	172		
Terminal Resistance			.29 ohms	.30	.30		
Inductance			.33 mh	.365	.35		
DOR + on Red			CW	CW	CW		
Friction Torque			10.9 oz in	10.9	11.8		
KE @ 1800 RPM			3.98V DC	4.03	3.96		

Sheet of

TII 25DCM1313

Hughes 445-1611 Rev. C

FACTUAL DATA

Test or Environment	Specification Values	Spec/Para Method/Condition	Unit No. 108	Unit No. 109	Unit No. 110	Unit No. 111	P.
Starting Current			4.0 A	3.8	3.5	3.8	
No Load Speed @ 21V DC			9100 RPM	8900	8800	8700	
Load Speed @ 23.2V	45 oz in		6600 RPM	6500	6400	6400	
22.7V	90 oz in		4200 RPM	4200	4000	3900	
Stall Torque @ 21.6V			172 oz in	172	172	172	
Terminal Resistance			.35 ohms	.36	.34	.37	
Inductance			.345 mh	.35	.345	.355	
DOR + on Red			CW	CW	CW	CW	
Friction Torque			12.7 oz in	12.7	10.9	11.8	
KE @ 1000 RPM			2.21 V	2.20	2.17	2.21	

Sheet 1 of 2

5/5/78

TII 25DCM1313

Hughes 445-1611 Rev. C

FACTUAL ' A

Test or Environment	Specification Values	Unit No. 112	Unit No. 113	Unit No. 114	Unit No. 116	Unit No. 117	Pa
Starting Current		4.7 A	3.4A	3.7	4.2	3.6	✓
No Load Speed @ 21V DC		9100 RPM	9200	8900	9000	8900	✓
Load Speed @ 23.2V	45 oz in	6400 RPM	6500	6400	6450	6400	✓
22.7V	90 oz in	3900 RPM	4000	3900	4000	3900	✓
Stall Torque @ 21.6V		172 oz in	172	172	172	172	✓
Terminal Resistance		.34 ohms	.33	.33	.34	.33	✓
Inductance		.355 mh	.34	.35	.34	.35	✓
DOR + on Red		CW	CW	CW	CW	CW	✓
Friction Torque		12.7 oz in	12.7	11.8	12.7	12.7	✓
KE @ 1000 RPM		2.14V	2.10	2.19	2.15	2.15	✓

Sheet 2 of 2

APPENDIX E

DEFINITION OF TERMS

PRECEDING PAGE BLANK-NOT FILMED

APPENDIX E

DEFINITION OF TERMS

MOTOR - Motor and drive sprocket are the only components in operation.

CHAIN - In addition to motor the chain and sprocket support are operational.

GENEVA - In addition to chain the Geneva mechanism and feeder sprocket and rotor are included.

NO BOLT - In addition to geneva the bolt-carrier without the bolt and striker assembly is included.

SAFE ON - In addition to no bolt the bolt and striker assembly are included. The safety knob is in the "SAFE" position.

SAFE OFF - ARC components, safety know is in the "FIRE" position.

FORWARD STROKE - Bolt-carrier is in motor towards front of gun; includes corners of chain operation.

FORWARD - Bolt-carrier is in stationary forward most position.

REARWARD STROKE - Bolt-carrier is in motion towards rear of gun. Includes corners of chain operation.

REARWARD - Bolt carrier is stationary in rearward most position.

DISTRIBUTION LIST

No. of Copies	Organization
12	Commander Defense Documentation Center ATTN: DDC-DDA Cameron Station Alexandria, VA 22314
2	Director Defense Advanced Research Projects Agency 1400 Wilson Boulevard Arlington, VA 22209
1	Commander US Army Materiel Development and Readiness Command ATTN: DRCMA 5001 Eisenhower Avenue Alexandria, VA 22333
1	Commander US Army Materiel Development and Readiness Command ATTN: DRCDMD-ST 5001 Eisenhower Avenue Alexandria, VA 22333
1	Commander US Army Materiel Development and Readiness Command ATTN: DRCDT 5001 Eisenhower Avenue Alexandria, VA 22333
1	Commander US Army Materiel Development and Readiness Command ATTN: DRCSF 5001 Eisenhower Avenue Alexandria, VA 22333
1	Commander US Army Materiel Development and Readiness Command ATTN: DRCQA-E 5001 Eisenhower Avenue Alexandria, VA 22333
1	Commander USA ARRADCOM ATTN: DRDAR-LC Dover, NJ 07801
2	Commander US Army Armament Research and Development Command ATTN: DRDAR-TSS Dover, NJ 07801
4	Commander US Army Armament Research and Development Command ATTN: DRDAR-SC, Mr. Gadomski DRDAR-SCW, Mr. Geeter DRDAR-SC, Mr. Kahn DRDAR-SC, Mr. Dahdouh Dover, NJ 07801
2	Director USA ARRADCOM Benet Weapons Laboratory ATTN: DRDAR-LCB-TL Watervliet, NY 12189
2	Commander US Army Armament Materiel Readiness Command ATTN: DRSAR-LEP-L, Tech Lib DRDAR-TSE-SW, R. Radkiewicz Rock Island, IL 61299
1	Commander US Army Aviation Research and Development Command ATTN: DRDAV-E 4300 Goodfellow Blvd St. Louis, MO 63120
1	Director US Army Air Mobility Research and Development Laboratory Ames Research Center Moffett Field, CA 94035

DISTRIBUTION LIST

No. of Copies	Organization
1	Commander US Army Electronics Research and Development Command Technical Support Activity ATTN: DELSD-L Fort Monmouth, NJ 07703
2	Commander US Army Missile Research and Development Command ATTN: DRSMI-R DRSMI-YDL Redstone Arsenal, AL 35809
1	Commander US Army Harry Diamond Labs ATTN: DRXDO-TI 2800 Powder Mill Road Adelphi, MD 20783
1	Commander US Army Communications Research and Development Command ATTN: DRDCO-PPA-SA Fort Monmouth, NJ 07703
1	Commander US Army Electronics Command ATTN: DELSD-L Fort Monmouth, NJ 07703
2	Commander US Army Mobility Equipment Research & Development Command ATTN: DRDME-WC DRSME-TST Fort Belvoir, VA 22060
2	Commander US Army TRADOC Systems Analysis Activity ATTN: ATAA-SA ATAA-SL, Tech Lib White Sands Missile Range NM 88002
4	Commander US Army Tank Automotive Research Cmd and Development Command ATTN: DRCPM-FVS DRCPM-FVS-G DRDTA-CV-D DRDTA-UL Warren, MI 48090
1	Commander US Army Infantry Center ATTN: ATZB-CDMSF, COL J. Jatch Fort Benning, GA 31905
3	Commander Naval Ordnance Systems Command ATTN: ORD-9132 Washington, DC 20360
2	Commander US Naval Weapons Center ATTN: Code 753 Code 12 China Lake, CA 93555
2	Commander US Marine Corps ATTN: AX Washington, DC 20380

Aberdeen Proving Ground

Dir, USAMSAA
ATTN: DRXSY-D
DRXSY-MP, H. Cohen
Cdr, USATECOM
ATTN: DRSTE-TO-F
Dir, USACSL
Bldg E3516, EA
ATTN: DRDAR-CLB-PA
Dir, USAMTD
ATTN: STEAP-MT
STEAP-MT-TI
Dir, USAHEL

USER EVALUATION OF REPORT

Please take a few minutes to answer the questions below; tear out this sheet, fold as indicated, staple or tape closed, and place in the mail. Your comments will provide us with information for improving future reports.

1. BRL Report Number ______________________________

2. Does this report satisfy a need? (Comment on purpose, related project, or other area of interest for which report will be used.)

____

____

____

3. How, specifically, is the report being used? (Information source, design data or procedure, management procedure, source of ideas, etc.) ______________________________

____

____

4. Has the information in this report led to any quantitative savings as far as man-hours/contract dollars saved, operating costs avoided, efficiencies achieved, etc.? If so, please elaborate.

____

____

5. General Comments (Indicate what you think should be changed to make this report and future reports of this type more responsive to your needs, more usable, improve readability, etc.) __________

____

____

____

6. If you would like to be contacted by the personnel who prepared this report to raise specific questions or discuss the topic, please fill in the following information.

Name: ______________________________

Telephone Number: ______________________________

Organization Address: ______________________________

____

____

— — — — — FOLD HERE — — — — —

Director
US Army Ballistic Research Laboratory
Aberdeen Proving Ground, MD 21005

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO 12062 WASHINGTON,DC
POSTAGE WILL BE PAID BY DEPARTMENT OF THE ARMY

Director
US Army Ballistic Research Laboratory
ATTN: DRDAR-TSB
Aberdeen Proving Ground, MD 21005

— — — — — FOLD HERE — — — — —